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HUMID HYSTERESIS OF MAHAJAN'S OPTICAL HYGROMETER AND OTHERS

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ABSTRACT. In this paper, humid hysteresis of Mahajan's optical hygrometer and some other types of hygrometers have been studied. The coercive time, residual humidity and humid hysteresis loop of hygrometers have also been explained.

It is observed that on traversing the path of a cycle of observations, the return path is different from the direct path, on increasing and decreasing the relative humidity respectively. This cycle of observations do not take the same path when repeated again. Its period is also reduced when it is repeated for some time without a break.

Almost all hygrometers exhibit the phenomena of humid hysteresis, coercive time, and residual humidity. The coercive time and residual humidity of a hygrometer are not of constant values, but they vary with the type of hygrometer depending on its construction, nature of its hygroscopic substance, rate of flow of air through it, and its immediate past history. The area enclosed by a loop of humid hysteresis decreases if such cycles are repeated for some times without a break.

In the previous papers the author has dealt with the construction and theory of working of Mahajan's (Mahajan, 1941) optical hygrometer. The time lag and humid fatigue of various types of hygrometers have also been studied. Now in this paper the author has attempted the study of humid hysteresis which is a phenomenon very commonly exhibited by various types of hygrometers, such as, Mahajan's optical hygrometer, hair hygrometer, paper hygrometer, humatograph etc. Their coercive times and residual humidities have been determined and discussed in detail. The method used and the results obtained are given below in brief.

APPARATUS

The apparatus used for the study of hysteresis of hygrometers, their coercive times and residual humidities is the same which was used by the author for measurement of time lag and humid fatigue of hygrometers and the same has been described in his previous paper on the said subject.

HUMID HYSTERESIS

The observations of variations of humidity as indicated by the optical hygrometer with respect to time were recorded in rapid succession without any break in cycles by exchanging the surrounding medium from moist to dry and vice-versa. A few sets of such cycles of observations are given below in Table I.

TABLE I

Mahajan's Optical Hygrometer

No. of set.	Cycle	Humidity-reading of surrounding medium.	Observation of humidity reading.	Time taken in minutes.	Remarks
1.	2.	3.	4.	5.	6.
I set.	I cycle (direct)	98·5 cm.	90·0	0	
			93·0	3	
			95·0	10	
			95·3	13	Time lag 22 min.
			97·0	17	
			98·3	22	
	(reverse)	91·0 cm.	98·3	0	
			96·0	2	
			95·0	7	
			93·6	15	
			93·3	22	Time lag 39 min.
			92·5	25	
			91·9	30	
			91·5	34	
			91·4	39	
II set.	I cycle (direct)	96·0 cm.	92·3 cm.	0 min.	
			94·7	3	
			95·3	8	Time lag 22 min.
			95·5	16	
			96·0	22	
	(reverse)	92·0 cm.	96·0 cm.	0 min.	
			95·8	1	
			95·6	3	
			95·3	10	
			94·3	15	Time lag 45 min.
			93·7	20	
			93·4	25	
			93·0	37	
			92·9	45	
	II cycle (direct)	100·0 cm.	92·7 cm.	0 min.	
			95·8	3	
			96·0	5	Time lag 17 min.
			96·6	10	
			100·0	17	
	(reverse)	92·0 cm.	100·0 cm.	0 min.	
			99·0	6	
			97·8	10	
			96·5	15	
			95·3	19	Time lag 38 min.
			94·0	23	
			92·5	32	
			92·3	38	
III set.	I cycle (direct)	88·0 cm.	81·5 cm.	0 min.	
			86·3	3	
			86·5	5	
			87·7	11	Time lag 18 min.
			88·0	18	
			88·0	23	

TABLE I—(*contd.*)

No. of set.	Cycle	Humidity-reading of surrounding medium.	Observation of humidity reading.	Time taken in minutes.	Remarks
1.	2.	3.	4.	5.	6.
	(reverse)	82·0 cm.	87·3 cm.	0 min.	
			87·0	1	
			86·0	2	
			85·3	7	
			85·0	11	
			84·4	13	Time lag 34 min.
			83·7	21	
			83·2	27	
			82·8	34	
			82·8	39	
	II cycle (direct)	86·5 cm.	81·5 cm.	0 min.	
			84·3	4	
			85·6	9	Time lag 11 min.
			86·2	11	
			86·2	14	
	(reverse)	82·0 cm.	86·2 cm.	0 min.	
			85·0	2	
			83·8	6	
			83·3	9	
			82·9	14	Time lag 23 min.
			82·6	18	
			82·4	21	
			82·3	23	
			82·3	25	

DISCUSSION OF RESULTS

The observations given in Table I set III have been plotted in curves given in figure 1, wherein the abscissa represents time in minutes and the ordinate readings actually recorded on on the Mahajan's optical hygrometer. They are the typical curves and of interesting nature.

In figure 1 the point *a* is the starting point. When a current of moist air is pushed inside the chamber its relative humidity increases rapidly with time in the beginning but this speed of rise of humidity slackens on regularly with time as is apparent from the curve *abcd*. If further observations are recorded the readings do not show any increase, as the steady state state has arrived and the curve represents the path *dc*, which is a horizontal line. The maximum time taken by the hygrometer to reach the steady state is t_1.

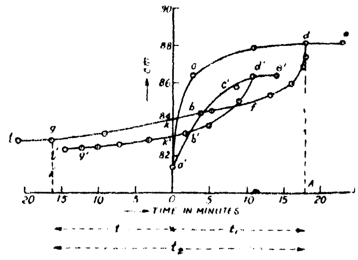

FIG. 1

Now the dry air is pushed into the chamber and the readings of relative humidity on the instrument are again observed at known intervals. These observations are represented by the part of the curve *dfbkg*. Here, the time has been counted in the reverse order from the point *d*—the starting point of the last steady state *de*. The direction for measurement of time is shown by an arrow in the figure. In this case A is the initial point and t_2 the maximum time taken by the hygrometer to reach the steady state *gl*. This portion of the curve *dfbkg* also shows that the relative humidity decreases very rapidly in the beginning but slowly later on, till a steady state *gl*—is reached. Thus the rate of change of humidity in the variable state varies with time in logarithmic relation as stated in the previous paper (Mahajan 1940), for it depends on adsorption of moisture or desorption of moisture by the soil or any other absorbant used in the hygrometer.

The portion of the curve *dfbkg* representing the return path is different from the former curve *abcd*. Thus the observations in the two cases differ. It further shows that the hygrometer reaches the steady state *gl* after time $t_2 = (t_1 + t)$ which is greater than the former time t_1. This return curve (ii) cuts the ordinate passing through *o* at *k*. Thus the additional time taken to reach the steady state is $(t_2 + t_1) = t$ minutes which has always some positive value in almost all hygrometers.

Now on repeating the same cycle of observations, it is observed that the observations do not traverse the old path of the former cycle but adopt a new one *abcdfkg* which is different from the former one *abcdfg*. This time the hygrometer reaches the steady state *de* and *gl* in comparatively shorter times. The additional time $(t_2 - t_1) = t$ is also less. Moreover, the area enclosed by the second loop is much smaller than that of the first one. This area becomes minimum when such cycles of observations are repeated a number of times without a break for the hygroscopic substance gets acclamatised to the variable conditions. But the shape of such loops remain almost the same which indicates that the nature of behaviour of these cycles is the same. The possible causes for traversing different paths of cycles are that firstly the hygroscopic substance in the hygrometer has its rates of adsorption of moisture and desorption of moisture slightly different and secondly the instrument has some time lag. It is, therefore, desirable that such a substance should be selected which has its powers of adsorption and desorption of moisture equal and these powers have linear relation with time. If these conditions are fulfilled no loop will be formed but the same path will be traversed on repeating the cycles.

Residual Humidity.—From the figure it is further evident that the value of humidity as represented by a hygrometer on its return cycle is not the initial one when the reversed time period AO is equal to the direct time period OA. The relative humidity on the reverse path is slightly higher than the initial humidity by *ak* which is the residual humidity of hygrometer. The value of this residual humidity is different in different hygrometers depending on their construction, nature of the substance used in them, rate of flow of air through them and their immediate past history. The values of residual humidity of some of the hygrometers are given in Table II below.

Coercive Time.—The extra time required to allow the hygrometer to come to its initial humidity is $(t_2 - t_1) = t$ as is indicated in figure 1. This is coercive time of a hygrometer. It varies with the construction of a hygrometer, nature of the substance used in it, rate of flow of air through it and its immediate past history. The values of coercive time of some of the hygrometers have been studied and are given below in Table II.

TABLE II

No. of set.	No. of Cycle.	Kind of hygrometer.	Residual humidity	Coercive time.
I set.	I cycle	Mahajan's	0·7 cm.	23 min.
	II cycle	optical-	0·4 cm.	21 min.
		hygrometer		
II set.	I cycle		1·3 cm.	16 min.
	II cycle		0·8 cm.	12 min.
Mean.			0·8 cm.	18 min.
I set.	I cycle	Hair-	6% H	8 min.
	II cycle	hygrometer	5% H	6 min.
II set.	I cycle		8% H	10 min.
	II cycle		6% H	8 min.
Mean.			6% H	8 min.
I set.	I cycle	Paper-	9% H	25 min.
	II cycle	hygrometer	6% H	21 min.
II set.	I cycle		10% H	27 min.
	II cycle		6% H	22 min.
Mean.			8% H	24 min.

Humid Fatigue.—The observations recorded in Table II indicate that the values of coercive time and residual humidity do not remain constant but decrease when such cycles of observations are repeated in rapid succession without a break. The details of this effect has already been dealt with by the author (Mahajan, 1944) in one of his previous papers on the subject.

Humid Hysteresis.—The effects produced by humidity of the surrounding medium tend to persist *i.e.*, tend to lag behind the cause. The reading of humidity given by a hygrometer is always slightly greater than what the humidity actually is when the relative humidity of the surrounding medium is diminishing, and it is always slightly less when relative humidity of the surrounding medium is increasing. Thus it always requires an additional time to bring relative humidity to the initial value or the actual value of the surrounding medium. This phenomenon of hygrometers is humid hysteresis (to lag behind). Hysteresis in this case is the lagging of relative humidity, as indicated by a hygrometer, behind the relative humidity of the surrounding medium which produces it.

Humid Hysteresis Loop.—The loop formed by the cycle of observations of humidity with respect to time is the hysteresis loop of humidity.

CONCLUSIONS

The results obtained from the above investigations are interesting and some of the important ones are given below:

1. The return path of a cycle of observations (when humidity is decreasing is different from the direct path of the same cycle (when humidity is increasing).
2. The cycles of observations do not traverse the same path when repeated again. The period of cycle is reduced when they are repeated for a number of times without a break.
3. Almost all hygrometers exhibit hysteresis of humidity.
4. Almost all hygrometers have their coercive time and residual humidity.
5. The residual humidity and coercive time are not constant but they vary with the type of hygrometer depending on its construction, its hygroscopic substance, rate of flow of air through it and its immediate past history.
6. The area enclosed by a loop of humid hysteresis decreases if such cycles are repeated for some time without a break.

Further work is in progress and will be published in due course of time.

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